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# Nitrogen dynamics associated with earthworm casts of *Martiodrilus carimaguensis* Jiménez and Moreno in a Colombian savanna Oxisol

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**Summary.** The effects of a large anecic earthworm species (*Martiodrilus carimaguensis* Jiménez and Moreno) on mineral soil nitrogen dynamics were studied in native and improved pastures on the eastern plains of Colombia. We compared the total C, total N, $NH_4^+$ and $NO_3^-$ contents in earthworm casts and in the non-ingested soil. Samples were taken at different times, up to 20 days after the casts had been excreted. The total C and N contents were several times higher in casts than in non-ingested soil in all pastures. Depending on the pasture, $NH_4^+$ levels were 5.2 to 28.3 times higher in casts than in soil. Mineral N increased rapidly in casts during the first few days after deposition and then decreased, reaching values 4.5 times higher than in the soil. The earthworm-induced mineralization was equivalent to 40 to 63 kg N · ha$^{-1}$ year$^{-1}$.

**Key words:** Earthworms, *Martiodrilus carimaguensis*, soil organic matter dynamics, N dynamics, acid soils

## Introduction

Earthworm activity represents one of the main regulators of soil organic matter (SOM) processes and their activity can improve soil quality (Lavelle et al. 1989). Several studies have shown that earthworm casts are enriched in N relative to the non-ingested soil (Syers et al. 1979). The influence of earthworms on N dynamics depends on the amount of soil that they ingest and the quality of material ingested. In the eastern plains of Colombia, Jiménez et al. (1998) estimated the cast production in the soil profile (surface and underground casts) by an anecic species to be 14.3 t dry casts ha$^{-1}$ yr$^{-1}$ in a native savanna and 378 t dry casts ha$^{-1}$ yr$^{-1}$ in an improved grass/legume pasture. The present work aimed to evaluate the effects of *Martiodrilus carimaguensis* (Oligochaeta; Glossoscolecidae) on nitrogen dynamics in different land management systems of the eastern plains of Colombia.

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## Materials and Methods

The study was carried out at the CIAT-CORPOICA Experiment Station of Carimagua (4° 37′ N, 71° 19′ W, 175 m.a.s.l.) in the eastern plains of Colombia. The annual rainfall ranges from 2100 to 2300 mm, and the mean annual temperature is 26 °C. Soils are well-drained silty clay Oxisols (fine, mixed, isohyperthermic typic Haplustox), with pH ($H_2O$) 4.5, Al saturation >80 %, low concentrations of Ca, Mg, K and P (Rao et al. 1993).

Sampling was carried out in three experimental plots, representing three different land use systems: (1) a native savanna (Sav), managed traditionally by burning every year during the dry season; (2) a 17-year-old improved pasture of *Brachiaria decumbens* cv. Basilisk (Bdec); (3) a 17-year-old improved pasture of *B. decumbens* associated with a tropical forage herbaceous legume species *Pueraria phaseoloides* CIAT 9900 ("Kudzu") (Bdec/Pp). Improved pastures, established on a previous savanna site, were fertilized with (kg $ha^{-1}$) 44 P, 40 K, 14 Mg and 22 S at establishment and with (kg $ha^{-1}$) 10 P, 9 K, 92.5 Mg and 11 S each second year for the next nine years (Lascano & Estrada 1989). Stocking rates for improved pastures were one cattle · $ha^{-1}$ during the dry season and two cattle · $ha^{-1}$ during the wet season.

Fresh cast samples of *M. carimaguensis* were marked and isolated in the field under three 1 × 1 m cage boxes, placed at random in each improved pasture, and in 4 × 4 m area in savanna. Daily fresh cast samples were isolated and maintained in field conditions to obtain total incubation times of 0.5, 1, 2, 4, 7, 15 and 20 days, where the cast samples reached equilibrium with the moisture of the soil. The samples were ground and passed through a 2-mm sieve. Total C and N (Kjendahl) and mineral N (colorimetric method) were determined. The amount of total N yearly digested by *M. carimaguensis* per hectare, which is released as mineral N, represents the overall N mineralization.

## Results

Total C content of bulk soil was 11 and 23 % higher under Bdec (22.64 g $kg^{-1}$) and Bdec/Pp (25.09 g $kg^{-1}$), respectively, compared with the native savanna (20.4 g $kg^{-1}$), but total N content showed no significant differences between treatments. The C-to-N ratio showed slightly higher values with improved pastures. Significant increments in total C content (3 times as much as in the soil) and total N (3, 4 and 5.3 times higher values in Sav, Bdec and Bdec/Pp, respectively) were observed in earthworm casts, compared with the bulk soil. Earthworm digestion greatly increased ($P < 0.0001$) the mineral N content in fresh depositions, compared with non-ingested soil (Fig. 1), mainly via higher N-$NH_4$ concentrations (162 to 223 μg $g^{-1}$ dry cast), i.e., 5, 9 and 28 times higher than in the soil in Bdec/Pp, Bdec and Sav, respectively). Nitrate-N content was reduced in fresh casts, compared with the soil in each system. This is equivalent to a mineralization of 3 to 62 kg N $ha^{-1}$ $year^{-1}$ in native savanna and improved pastures, respectively (14 and 21 % of total N digested by the earthworm). Mineral N showed little increments in the first days after deposition (Fig. 1), and then constantly decreased, reaching values 3 and 18 times greater than in the non-ingested soil in all plots studied, representing 2, 15 and 40 kg N $ha^{-1}$ $year^{-1}$ in Sav, Bdec and Bdec/Pp, respectively.

## Discussion

Higher total C and total N contents in the earthworm casts, compared with the bulk soil, can be explained by the capacity of the worm to select substrates with high organic contents (Lavelle et al. 1992). The greater increments in casts from improved pastures probably results from a higher quality substrate ingested by the worm, especially legume-derived soil organic matter (Rao et al. 1993). Increments of mineral N by accumulation of N-$NH_4$ in fresh casts is the result of the excretion of ammonia through endonephridia into the gut, and the mineralization of soil organic matter by the ingested soil microflora in the middle and posterior part of the gut (Lavelle et al. 1992). Between 79 and 96 % of the total mineral N released in fresh casts is the result of earthworm digestion. Low N-$NO_3$ contents in fresh cast corroborate that nitrates are not an earthworm metabolic product (Lavelle et al. 1992). The decrease of mineral N with time probably results from the transformation of N into the microbial biomass and los-

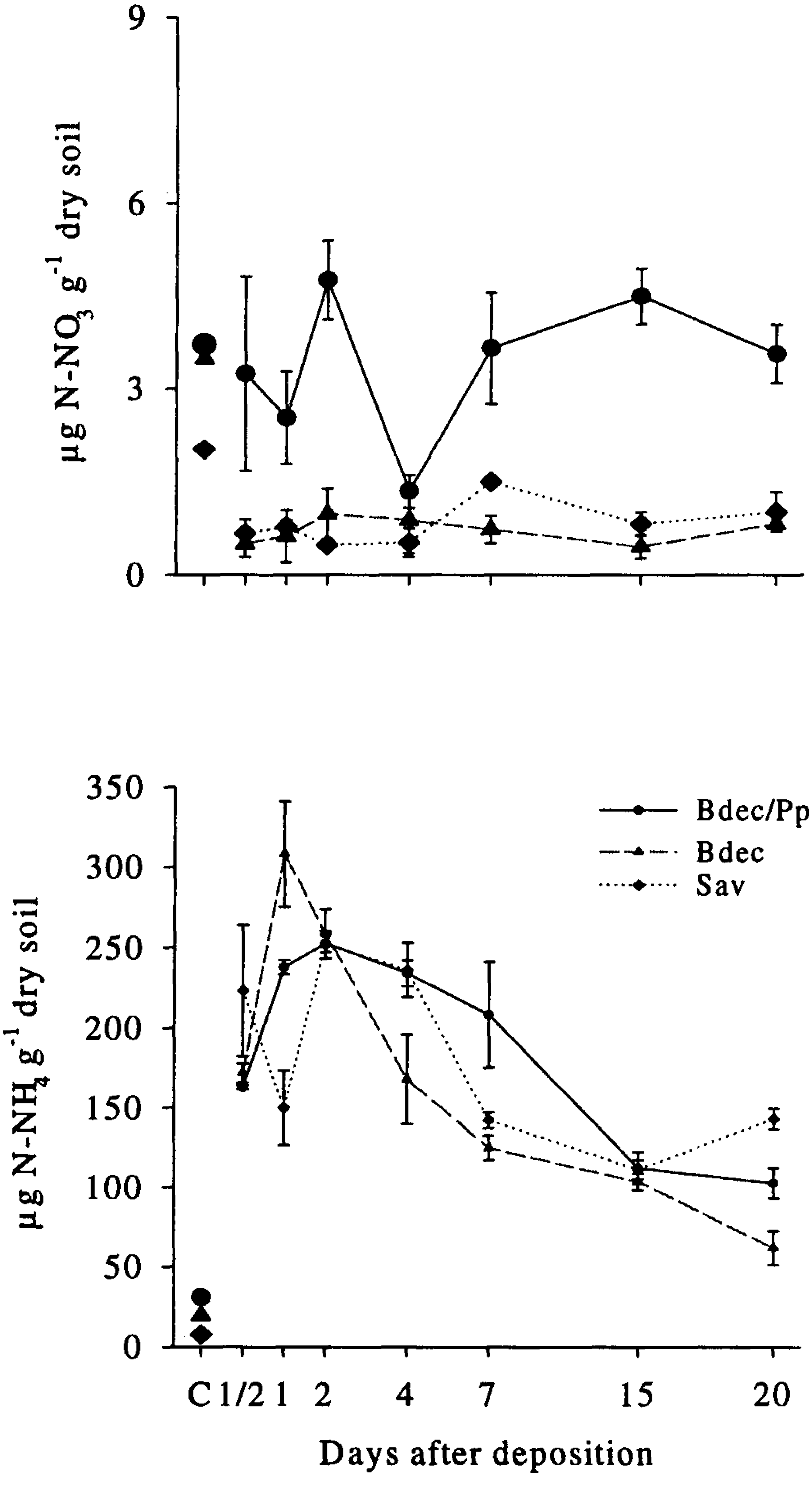


**Fig. 1.** Mineral N dynamics in the casts of *M. carimaguensis* in different land management systems at Carimagua. Bdec/Pp: *Brachiaria decumbens/Pueraria phaseoloides*, Bdec: *B. decumbens*, Sav: native savanna, C: non-ingested soil

ses by volatilization, denitrification or leaching (Lavelle et al. 1992). Long-term experiments conducted with the same species, showed that mineral N was increased in the surrounding soil after deposition with further increments of N-$NO_3$, which represented N diffusion from the casts to the soil (Decaëns et al. 1999).

Although native savannas showed the greatest N mineralization rates (214 µg N $g^{-1}$ dry soil), the high differences in yearly mineral N released per hectare in the improved pastures can be explained by a greater total earthworm biomass per area and the amount of soil that they ingest (Jiménez et al. 1998), reflecting the importance of the land system in the earthworm activities.

## Conclusions

The introduction of improved pastures into native savannas resulted in increases in elements of the soil organic matter (SOM) pools, which increased the density and activities of earthworm communities. Earthworm digestion results in high concentrations of soil organic matter in their deposition, and higher overall nitrogen mineralization. The magnitude of these changes depends on the soil organic matter and litter quality consumed by the worm. The large amounts of mineral N released in improved pastures is a result of high earthworm densities that ingest several hundreds of tons of soil yearly per $ha^{-1}$.

The management of earthworm communities on improved pastures could be a mechanism to increase SOM and nutrient turnover, especially N, reducing the risk of pasture degradation. Future long-term investigations about earthworm effects on soil quality should focus on the implications for system sustainability.

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